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Mars Pathfinder Active Thermal Control System: Ground and Flight Performance of a Mechanically Pumped Cooling Loop

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ABSTRACT

A key element of the Mars Pathfinder thermal control system is the Heat Rejection System(HRS). The HRS of Mars Pathfinder is designed to actively control the temperatures of the various parts of the spacecraft. The system is designed to keep the lander and cruise stage electronics between -30 to +40 C during the entire seven month cruise from Earth to Mars, This is achieved by mechanically circulating single-phase Freon 11 liquid through the lander and cruise electronics box heat exchangers and transferring heat to an external radiator on the cruise stage. This is the first time in spacecraft history that a mechanically pumped cooling loop has been used on a long duration spacecraft **mission.**

The HRS which consists of the Integrated Pump Assembly(IPA), radiators, electronics box heat exchangers, filter, and associated tubing was designed, fabricated, installed and tested on the Pathfinder spacecraft during the June 1994 to June 1996 period. Pathfinder will be launched in December 1996 for a Martian landing in July 1997. The HRS will be operating continuously throughout the entire seven months of cruise to Mars, The IPA, which is the heart of the HRS, circulates and controls the working fluid in the HRS during this cruise in order to transfer excess heat from the various spacecraft parts to the radiator.

The important Pathfinder requirements for the HRS were: 1) heat transfer rate of 90 to 180 Watts, 2) a total mass of less than 18 kg (including 8 kg for IPA), 3) maximum power consumption of 10 Watts, 4) two years of continuous operation, and 5) redundancy for the active components of the IPA. The other HRS requirements were concerned the Freon operating pressures, flow rates, pressure drops, radiator bypass flow rates, and the leakage rates.

The major elements of the IPA are: two centrifugal pumps, an accumulator, two thermal control valves, four check valves, and the motor control electronics. Only one pump/thermal control valve is needed to circulate the Freon 11, the working fluid, in the system. The other set of pump/thermal control valve acts as a backup. The pump is rated to produce 6 psid at a rated flow of 0.2 gpm of Freon 11 in the -30 to +30 C range. The motor control electronics are designed to operate the pump motor at the rated performance over an input power of 27 to 36 Vdc. The maximum operating pressure of the system is 95 psia. The accumulator keeps the operating pressure 30 psig above the saturation pressure of Freon at the operating temperature.

The **first** IPA unit was fabricated and flight qualified in February 1996. It was installed on the spacecraft in March 1996 and the whole HRS went through spacecraft acoustic and system thermal vacuum tests. The performance of the HRS, specifically the IPA, was carefully

monitored during the entire spacecraft ground operations. The thermal, electrical, and hydraulic performances of the 111{S have more than satisfied the Pathfinder requirements. The I IRS performance will be continued to be monitored during the remainder of the ground operations and also during the entire flight operations.

Many lessons have been learned during the testing and ground and flight operation of the HRS. Several modifications arc being made to the operation of the HRS based on these lessons. Since it is the first time such a mechanically pumped cooling loop is flown for deep space missions, there is a lot of interest in its performance and reliability. The only other space application of the mechanically pumped loops has been for the Space Shuttle where they were used for short duration (less than one month at a time) flights.

The paper will present the performance of the mechanically pumped cooling loop during the ground and flight operations. Based on the lessons learned from this experience, recommendations on the design and operation of the pumped cooling loops for future space missions will be made.